ADDITIONAL NOTES ON THE GENUS *GMELINA*. I

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Herewith follows the start of a series of additional notes in continuation of my first paper on this genus published in the last previous issue of the present journal. More may be expected to follow as space becomes available.

GMELINA ARBOREA Roxb.

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A medium-sized to large, unbuttressed, deciduous tree, to 20 m. tall, wide-spreading (in the open), with a good canopy, rapid-growing, often branched to the base when young easily grown from seed, the young parts densely tomentose; trunk straight or rather irregular, cylindric, to 2.5 m. girth, the bole clear to 10 m. on old trees, usually with 3 or 4 rings per inch of radius; bark smooth or warty, with lenticular tubercles, dark-gray, pale-ashy, or light-gray to grayish-white, grayish-yellow, brownish-white, or white, with blackish patches and conspicular circular lenticels, rather corky, exfoliating in thick, irregular, woody plates which leave shallow depressions, or in scurfy lighter-colored flakes or scales when old, the blaze pale-orange, freely mottled with darker orange; inner bark mottled yellow, rapidly turning brown on exposure to air; wood light, weight 28--40 (or 50 when wet) pounds per cubic foot, averaging 36 pounds, 13.50 kg. per cubic foot or 600 kg. per cubic meter, very durable, white or grayish to yellowish- or reddish-white or even light yellowish-brown when fresh, coarse-textured, closely even-grained, soft, strong, tough, with a glossy luster, seasoning well without warping or cracking, easily worked, taking a good polish, easily painted or varnished, usually quite resistant to termites and shipworms (*Teredo*), the annual rings more or less distinct, with numerous very fine, prominent, moderately broad and short medullary rays visible in the silver grain as irregular horizontal bands, the pores of different sizes, mostly large in the spring wood, often subdivided, rather prominent in a vertical section, sometimes arranged in rough, more or less concentric lines,, the blaze thick, pale-yellow or white to greenish-white, turning brown, green below the cuticle; branches few (when old) or numerous (when young),

spreading, forming a large shady crown; branchlets and young parts subpubescent to yellowish-tomentose, tetragonal; leaves simple, deciduous, decussate-opposite, mostly rather soft and limp, with an apical drip-tip; petioles cylindric, 4--15 cm. long, puberulent or glabrous, those of a pair often unequal; leaf-blades spinach-green above when young, pale chrome or straw-color when old, subcoriaceous, broadly ovate, 10--25 cm. long, 4--20 cm. wide, apically long-acuminate or caudate, marginally entire on mature plants, basally usually cordate or subcordate to truncate, usually with a short and abrupt central cuneate attenuation into the petiole, densely tomentose above when young, becoming glabrous above when mature, permanently densely fulvous-tomentose or fulvous-tomentellous with stellate hairs beneath, some or all of the leaves with 1--several large glands (nectaries) between the larger veins just above the petiole apex on the basal attenuation; lateral secondaries 5--10 pairs, the lowest pair basal or sub-basal and strong; tertiaries small, more or less parallel; inflorescence racemose, terminal and axillary, strictly dichotomous, fulvous-tomentose throughout, erect, 3--39 cm. long, some with a few single flowers in the leaf-axils; bracts linear or linear-lanceolate to subulate, 3--10 mm. long and 1--2.5 mm. wide, apically acuminate, caducous, neither foliaceous nor brightly colored, densely villous on both surfaces; pedicels 1.5--3 mm. long; flowers large, handsome, appearing before or with the young leaves, about 3.8 cm. long and 2.5 cm. wide, arranged in 1--3-flowered [usually 1-flowered by reduction] cymules on the decussate-opposite panicle-branches, ornithophilous; calyx broadly campanulate, 3--5 mm. long, externally densely appressed-pubescent or fulvous-tomentose, with 1--4 discoid nectariferous glands, the rim with 5 small, triangular, apically acute teeth, internally glabrous; corolla large and showy, 3--4 times as long as the calyx, somewhat like that of *Catalpa*, varying from yellow or yellow tinged with brown to brilliant orange , reddish- or brownish-yellow, dull yellow-brown, pinkish-brown, orange-yellow, or orange-whitish, often dull-chestnut with a yellow lip and throat, mostly deep tawny-yellow within and paler outside, 2.5--4 cm. long, about 2.5 cm. wide, pentamerous, tubular for the lower 1/3 or 5--6 mm., obliquely ampliate and funnelform (10--12 mm. wide) at the throat, externally velutinous to tomentose or densely appressed-villous, internally with glanduliferous hairs, the tube often madder-purple. deeply divided into 2 oblong, apically obtuse, backwardly curled lips, the upper lip short, often at first straight, 2-lobed with ovate apically rounded lobes 7--10 mm. long, 12--15 mm. wide, the lower lip often lemon-yellow, about as long to twice as long as the often dull orange-pink upper one, 3-lobed, the ovate or shovel-shaped middle lobe much longer and broader than the 2 obovate, rounded, 15 mm. long middle ones, broadly rounded, about 15 mm. long and 20--25 mm. wide, often yellow and ribbed on the upper surface, pale on the lower surface, projecting forward (antrorse), apically subobtuse and with an irregularly crenulate margin; stamens 4, didynamous, exserted from the mouth of the corolla-tube, sometimes one pair sterile, 13--15 and 17--20 mm. long; anthers oblong, 2.5--3 mm. long, the 2 thecae parallel and separate; pollen grains 3-zoni-

colporate, prolate spheroidal, 29 x 35 mu (range 33--44 x 32--39 mu), the colpi ends acute, tenuimarginate, the membrane minutely crustate, the apocolpium diameter 3.5 mu, the endocolpium very faint, the exine 1.4 mu thick, the ectine almost as thick as the endine, its surface reticulate, the lumina very small; pistil exserted from the mouth of the corolla-tube; style slender or filiform, glabrous; stigma shortly bifid; ovary 4-celled, externally glabrous, each cell 1-ovulate, the ovules attached near the top of the cell; fruit drupaceous, ovate to oblong or obovoid-pyriform to subrotund, 2--3 cm. long, 1.5--2 cm. wide, borne on the mostly unenlarged fruiting-calyx, at first green but yellow or yellow-orange when mature, succulent, aromatic, bitter-sweet, resembling that of *Spondias*, the pericarp leathery and shiny, the exocarp succulent and sweetish, the endocarp bony, usually 2-celled and (by abortion) 1- or 2-seeded, sometimes 3-celled and 3-seeded; seeds exalbuminous; chromosome number: 2n = 36, 38, or 40.

This species is based on an unnumbered Rottler collection probably now deposited in the East India Company herbarium at Kew, originally from the Coromandel coast of India.

Smith's original description is: "*G. arborea*. Roxb. MSS. (*Cumbulu*; Rheede Hort. Mal. v. 1. 75. t. 41) -- Leaves heart-shaped, undivided, pointed, downy beneath; their lateral ribs cloven. Thorns none. -- Sent from the coast of Coromandel by the Rev. Dr. Rottler, with the above name of Dr. Roxburgh. Gaertner has most justly pointed out the *Cumbulu* of Rheede as a *Gmelina*, though quoted by Linnaeus, doubtingly indeed, for his *Bignonia Catalpa*. This is a tall and upright tree, growing in sandy ground, with downy branches, and large, opposite, stalked, heart-shaped, entire leaves, downy and veiny beneath. Thorns none, as far as we can learn. -- The flowers are numerous and handsome, yellow, growing in compound, hairy, terminal clusters. Fruit yellow, obovate, rather small."

The species is native from Pakistan, Bhutan, India, and Sri Lanka, east through Bangladesh, Burma, and Thailand to Indochina, Malaya, and Indonesia, and north to southern China. It has been introduced for shade, fuel, timber, and paper-pulp in several parts of tropical Africa [Ghana, Nigeria, Sierra Leone, Malawi, Tanzania, Uganda, Zimbabwe, and South Africa] and South America [Brazil and Venezuela], often in extensive plantations from which it tends to escape and become naturalized; also in lesser quantity in Central America and the West Indies [Mexico, Belize, Honduras, Cuba, Puerto Rico, and Dominica] and the oceanic islands [Fiji, Hawaii, and the Philippines]. In India it is sometimes planted along avenues for shade and as an ornamental or decorative tree in parks and gardens. In Sri Lanka my wife and I saw it being used for shade in temple gardens.

Collectors describe the tree as varying from shrubby to large, 5--15 m. tall or 20--60 feet tall, the trunk 15--36 inches in diameter at breast height and 61 inches in girth, often branched from the base (when young), the crown rounded, the bark 1 cm. thick, varying from gray or grayish to yellowish or yellowish-gray or even brown, tuberculate-roughened, finely fissured, the cut surface yel-

low and brown streaked, the wood "fading yellow", the leaves opposite, green, deciduous, hairy beneath and with nectaries at the base, the flowers fragrant or slightly so, the stamens "2 plus 2", and the fruit at first green, then yellow, finally light-brown, bittersweet, "cherished by antelopes". Collectors have encountered it at altitudes of 50 to 1650 meters, in anthesis from August to May and in fruit in February, from April to July, and in October. They have found it growing in fields and hedges, along roadsides, in open ground and on flat land, in jungles, deciduous and open deciduous forests, subtropical evergreen forests, on hill slopes, sandstone ridges, and steep disturbed mountainsides, in dry bamboo brakes, along streamsides, and in patana grassland, in the light shade of forest edges (but not in deep shade), in scrub jungles, on savannas, and in areas of 87--95 inches of rainfall per year.

The corollas are described as "yellow" on *Henry 12886*, *Koyama & al. 15535*, *Saldanha 12346 & 13298*, *Sangdhachand 780*, *Sumithraarachchi & Fernando DBS.161*, and *Wendt & al. 2916*, "madder-purple, yellow in throat and lip" on *Chand 4398*, "yellow to brown" on *Saldanha 16581*, "brownish-yellow" on *Molina R. 27891* and *Saldanha 12824*, "dull yellow-brown" on *Nafday 174*, "yellow and brown" on *Bailey 809*, "yellow and pinkish" on *Phillips 2773*, "yellowish-brown" on *Kokkam Kaeng 4*, "reddish-yellow" on *Kadir s.n.*, "brown with yellow lower lip, throat purple" on *Sumithraarachchi DBS.663*, "yellow with brownish petal-tips" on *Gentry 12805*, "yellow, pink outside, hood and edge of wings also pink" on *Chand 7476*, "lip broadly yellow-edged" on *Chand 3045*, "brown, yellow in tube, mouth tinted purple, lip bright-yellow" on *Stevens 20955*, "whitish-yellow with brown" on *Bunpheng 1080*, "madder purple, lip and bowl yellow" on *Koelz 33086*, "pinkish-brown, lip and tongue yellow" on *Chand 8344*, "clouded rose-purple, lip yellow" on *Chand 1443*, "crimson, lip yellow" on *Chand 4603*, and "purplish-red, yellow-pubescent inside, tube and labellum yellow inside" on *Kanis & al. SAN.52638*, while *Mejía 253* is said to have had the "flores amarillas por dentro y rojo claro por fuera".

Bunphang reports the species common in evergreen forests in Thailand and Sangkhachand found it common in lowland evergreen forests there; Ward tells us that it is "common but scattered in subtropical evergreen forests, leafless or almost so when in full bloom" in Burma in April. Saldanha reports it "common in deciduous forests, occasional in semi-evergreen forests" in Mysore, India. Sumithraarachchi avers it to be "rare on hilltop savannas" in Sri Lanka; Kokkam Kaeng describes it as a large tree "common in dry mixed deciduous forests" in Thailand. My wife and I found it occurring as scattered trees on steep forested slopes in Sri Lanka. Saldanha refers to it both as "occasional" and as "fairly common" in Mysore.

The *Premna tomentosa* of Miquel, referred to in the synonymy (above), is based on *Hohenacker 554* from Kerala, India. The homonymous *Gmelina tomentosa* Roxb. is a synonym of *G. asiatica* L. and *G. tomentosa* Fletcher is a valid species.

Gmelina arborea is of considerable economic importance and has accumulated a large literature. Brandis (1874) calls it "A widely spread tree through the greater part of India, Burma and Ceylon. In

the sub-Himalayan tract it extends to the Chenab, ascending to 3,000 feet and even higher, but is scarce in the Panjab. Grows on the dry hills of the Aravalli range near Ajmir. Not gregarious, and nowhere abundant. The leaves are shed Feb.--April, the new foliage appears April--May. Fl. generally before the leaves, Feb.--April. Fruit ripens May--June."

Kurz (1877) says that the tree is "Frequent all over Burma from Ava and Chittagong down to Tenasserim and the Andamans, especially in the upper mixed forests and also in the tropical forests, but rarely entering alluvium, up to 3,000 feet elevation." In his 1875 work he lists it from the upper mixed forests and evergreen tropical forests of Pegu, describing the wood as white, light, "resembling mutchi wood", weighing 35 pounds per cubic foot, "used [in Pegu] often for making canoes and boats, also for house-posts, planks, clogs and for carving images. Recommended for furniture." Deb (1981) lists it from Tripura.

Schauer (1847) cites unnumbered collections of Edgeworth, of Roxburgh, and of Perrottet, as well as *Wallich 1817* in the DeCandolle Herbarium at Geneva, all from eastern India. Trimen (1895) tells us that in Sri Lanka it is found in the "Moist region up to 5000 ft.; rather common, but often cultivated. Fl. March; 4 upper lobes dull orange-pink, lower one lemon-yellow.....The flowers suggest a Bignoniaceous plant. They appear along with the young foliage, the tree being deciduous."

Talbot (1909) says that the species occurs in "Tropical and subtropical India up to 5000' in deciduous forests, Burmah, Bengal, Chittagong, moist region of Ceylon; throughout the [Bombay; Presidency scattered in monsoon-forest but nowhere common, on the Turanmal plateau Khandesh Satpudas, 3700'", flowering there in March and April, fruiting in May and June.

Hallier (1918) cites his *nos. C.243* and *3514* from Sri Lanka and *Hosseus 476* from Thailand. Parkinson (1922) lists the species from the "upper mixed forests", citing an unnumbered Kurz collection, but adds that "The Andaman specimens have been collected only in Port Blair where it may have been introduced and planted. I do not think it is a native of the [Andaman] islands." Parker (1924) lists it from the Punjab as "Not common" in the sub-Himalayan area from Ravi eastward, but "Often cultivated in the plains".

P'ei (1932) cites from Yünnan, China, only *A. Henry 12886*. He notes that "The Yunnan plant agrees very well with the Indian material except that its leaves are not as large as described by Roxburgh. It is allied to *Gmelina asiatica* L., from which it differs by its erect inflorescences, and large leaves."

White (1962) refers to trial plots planted in Zambia. Dop (1935) cites unnumbered collections by Chevalier from Tonkin, by Harmand and by Poilane from Annam, by Harmand and by Thorel from Laos, and by Hosseus and by Kerr from Thailand.

Haines (1910) describes the bark as "light grey, sometimes lightly and transversely furrowed, flaky in isolated light coloured patches when old, thick. Blaze with a thin chlorophyll layer, then thick pale yellow with rough cut, then white with soft cut. Inside

(on wood) yellowish."

Lamb (1968) gives a detailed discussion of this species as to description, flowering and fruiting, leaf-fall, root system, habitat conditions in relation to climate, physiography and ecologic associations, longevity and growth patterns, seed production and quality, seed distribution, causes of damage to seeds, natural and artificial regeneration, seed germination, seedling characters, recommended methods of sowing, nursery care, preparation of plantation sites, planting and tending of seedlings, spacing, nutrient requirements, thinning and pruning, growth rate, yield, parasites, pests, fungal diseases, frost, fire, and wind damage, physical and mechanical properties of the wood (including macroscopic and microscopic features), seasoning and shrinkage, durability, preservation treatment, etc. According to him "The bark on young trees and on the crown and upper part of the stem in older trees, is smooth, corky pale brown to grey in colour. It exfoliates near the swollen base of the stems in trees over five to eight years old exposing smooth paler coloured bark beneath. Form varies greatly with varying conditions of growth. If grown in the open, heavy branches and a wide crown develop and the stem is short, seldom straight, swollen at ground level and markedly tapered; if grown in well thinned plantations on high quality sites, the tree attains a height of 100 feet in 20 years, a girth of 6 to 8 feet at breast height, a clean nearly straight stem, with much less taper and a domed crown. Trees of this form have been reported in natural forest in Burma.....The leaves fall as a rule about January--February in its natural habitat; the new leaves appear in March--April. The panicles of flowers appear from February to April when the tree is more or less leafless, or with the young leaves.....The root system varies in depth of penetration with soil depth and texture. Roots have the same pale corky bark at the ground surface as the branches." It is "a short lived tree everywhere but lives longer and grows larger where deep moist soil amply supplied with moisture occurs." It is "a transitory species in rain forest springing up where a hole occurs in the canopy and growing rapidly on the accumulated fertility occurring in such gaps. It will grow equally well in deciduous high forest on the deep river alluvia." It will start to grow on dry, shallow, sandy, or otherwise poor soil, but will remain stunted. "It is sensitive under these conditions to competition from weed species, especially grasses, and fails to suppress them; the leaves turn yellow, the canopy lightens and tree growth slows down. However, in savanna woodland and on sites of abandoned villages and old cattle kraals in Africa, the stimulus from the residue of nutrients in the soil causes vigorous growth, a dense closed canopy and clean forest floor, and produces stems useful for poles."

In the mixed deciduous forests of the Central Provinces of India it grows in association with *Tectona grandis, Terminalia tomentosa, T. belerica, Lagerstroemia parviflora, Ougeinia dalbergioides, Anogeissus latifolia, Dalbergia sissoo, D. paniculata, Pterocarpus marsupium, Diospyros melanoxylon, Acacia catechu, Chloroxylon scietenia, Soymida febrifuga, Schleichera trijuga, Schrebera swie-*

tenioides, *Cleistanthus collinus*, *Odina wodier*, *Cassia fistula*, *Bridelia retusa*, *Adina cordifolia*, *Stephegyne parvifolia*, *Butia frondosa*, *Bassia latifolia*, *Phyllanthus emblica*, *Buchanania latifolia*, *Xylia xylocarpa*, and the prevailing bamboos, *Dendrocalamus strictus* and *Bambusa arundinacea* (along rivers).

Lamb avers that *Gmelina arborea* "grows very rapidly during the first six years of its life with the production of heavy branches when the trees are widely separated and a very tapered bole. With competition from neighbours the branches are kept small and the taper of the stems is greatly reduced. By the seventh year rapid height growth slows down." In unfavorable sites it may die in its twelfth year even without attack from a primary pathogen, "but in the best alluvial sites in a monsoon climate it may live to be at least 30 or 40 years of age. It is however a short lived tree."

Trees as young as 3 or 4 years may produce fruit, ripening from the end of April (in Burma) to July (in India) and "fruiting is regular and usually plentiful each year.....about 640.....per pound." The rate of germination of fresh seeds is high, but decreases rapidly in storage.

"On sandy soils in the open, around *Gmelina* plantations in Eastern Nigeria and Sierra Leone, natural regeneration is prolific....The seed will germinate under the thinned out canopy of a [suddenly destroyed] plantation". Germination is epigeous, resembling that of Teak. The stone of the drupe opens by means of one or two lateral valves, the radicle emerging first, the cotyledons issuing shortly after. The stone is either left on the ground, or is carried up over the cotyledons, falling with their expansion."

Streets (1962) describes efforts to introduce *Gmelina arborea* into various parts of the British Commonwealth, with only varying degrees of success. In some areas, however, it has produced an average growth of 50 feet and a diameter of 6.4 inches in 21 years, with 450 trees per acre; in other areas an average of 45 feet in 10 years with a rapid suppression of weedy undergrowth. It coppices well.

Prain (1963) lists the species from Chota Nagpur, central and western Bengal, and Chittagong. Kanjilal and his associates (1939) assert that it is "common" throughout Assam. Cooke (1958) cites unnumbered collections by Dalzell & Gibson from Konkan, by Woodrow from Deccan, by Ritchie and by Talbot from Kanara, and by Woodrow from Gujarat. He also cites a Dalzell & Gibson collection from Sind, but admits that it was from "introduced" material. He gives the species' overall distribution as throughout India, Ceylon, and the Malayan [and, erroneously, the Philippine] islands. Parham (1964) reports it introduced and moderately common in the Fiji islands.

Gamble (1902) tells us that "This handsome and useful tree is to be found throughout India, except in very dry localities, but is never gregarious and nowhere very common. In the Lower Himalaya and Sub-Himalaya it is met with in the moister parts of the Sál and mixed forests, and in similar places in the C[entral] P[rovinces], Berer, Bombay and South India. It is most common in Eastern Bengal and

Chittagong [in Bangladesh], and also in Burma. It is often planted as a garden tree and in avenues, and seedlings grow very fast in suitable soil. It coppices very well. It has large yellow flowers and a large fleshy drupe." Graham (1839) lists it from Bombay island, India, and assures us that it is "Common throughout the Concans". Dastur (1952) describes the species as "Scattered over a large part of Tropical and Subtropical India and Pakistan, up to 5,000 ft. in deciduous forests". The wood "is one of the best and most reliable timbers; it can easily be painted and varnished."

Hains (1922) avers that the typical form of *G. arborea*, with its stellate pubescence on the lower leaf-surface, is found "only....in the extreme north of the province [Bihar & Orissa], if at all." Barnard (1955) discusses in detail the general problems involved in attempts to use this tree in afforestation or reforestation projects in Malaya.

Srivastava (1967) informs us that the species is called "vidari" and "vidarini" in the ancient Charak Samhita, but is now called "gambhari" and "kasmari" in the Ayurvedic materia medica of India. In his later (1976) work he cites his *no. 1293*, noting that the tree is "Frequent in and around the forest. Most of the flowers fall off even before pollination [and so] only a few fruits develop."

Menninger (1944) says of *Gmelina arborea*: "This is a charming tree of shady localities and the lower hills throughout India. Ida Colthurst in 'Familiar Trees in India' says: 'Nature, always inimitable in her choice of harmonizing colors, perhaps nowhere excels herself as when she blends yellow and browns; and a good example of this art is the exquisitely scented bloom of *Gmelina*. The flower appear on a naked tree, from the end of February right on to mid-April, and in shape bear some resemblance to *Antirrhinum* (Snapdragon). They have five petals, four of which are tawny, and the fifth a bright yellow which in the bud is bent inwards and protects the dark ones. The leaves, broad (6 x 9 inches), are heart shaped and ending in a point, appear as soon as the season of blooming is over.' The leaves are dark green and glossy on the upper surface, pale green underneath. Sturrock says it is a handsome, unarmed tree requiring rich soil. Corner's 'Wayside Trees of Malaya' calls the flowers 'orange yellow', says they are often in clusters a foot long at the tips of the branches and from the leaf axils. The tree, usually 50 to 60 feet, grows much larger in Burma and is valued for its timber because it 'lasts well under water, better than teak'," In a later work (1962) he asserts that in Florida (U.S.A.) the tree can withstand winter temperatures as low as 20° F., its blossoms, appearing when the foliage is thin or absent, "put on a good show", and mature specimens are growing in Ocala, Fort Myers, and Stuart, Florida.

Ali (1932) reports that the flowers appear to be well adapted to bird-pollination and are mostly serviced by the sunbirds, *Leptocoma asiatica* and *L. zeylonica*, throughout daylight hours.

Cave (1964) records the haploid chromosome number as 19, but S. & G. Manguenot (1962) give the diploid number as 36, while Raman & Keszvan (1963) give it as 38. Possibly different varieties of the

species were used in obtaining these diverse figures. Hopefully, herbarium vouchers were made and are preserved somewhere so that the exact identification can be checked!

Joseph & Vajravelu (1967) cite their *no. 14005*; Kammathy (1967) cites his *nos. 73667, 79893, 80056,* & *80207*, referring to the species as "common in moist deciduous forests dominated by *Terminalia tomentosa*, where it is mostly overtopped by *Wendlandia thyrsoidea*". Santapau & Raizada (1955) call it a rare tree (in the wild) in the Gir of India, but note that "we have seen.....a fairly large number under cultivation in forest nurseries", citing four unnumbered collections, one of which was labeled as "common in field hedges". Saxena (1970) cites only *Saxena & Khotele 5908*.

Venkatareddi (1969) describes the tree as only "occasional in deciduous forests" and cites his *nos. 96045, 97700,* & *100973* and *Gammie 15168*. Vyas (1964) reports it "common in the luxuriant growth of cool and shady valleys in the Sub-Himalayan areas", while Agarwal (1970) also lists it from the Sub-Himalayan tract from Chenab eastward and "throughout India, Burma and Andamans". Ellis (1968) cites his *no. 23736* from Andhra Pradesh, where Sebastine & Henry (1966) found it to be "rare along roadside", citing only their *15958*. Rao & Rabha (1966) list it from Assam.

Longman (1969) reports that, in his experience, night temperatures of 26° C. will lead to bud dormancy in some individual trees, but not in all.

Puri (1960) found *Gmelina arborea* to occur naturally in the second story in north Indian lower alluvial savanna forests in Bengal along with *Bombax malabaricum, Callicarpa arborea,* etc.. and asserts that it follows a phytogeographic pattern of nearly uniform distribution throughout India except for the desert area. In the northern sub-Himalayan tropical semi-evergreen forest on lower hillslopes it is one of the common associates of teak (*Tectona grandis*). It occurs in the sandalwood tropical moist deciduous forests in Mysore, Madras, Bombay, and parts of Madhya Pradesh in association with *Artocarpus hirsuta, Eugenia jambolana, Vitex negundo*, etc. It occurs in the upper story with *Bombax malabaricum* in edaphic, Gangetic, tropical, moist, deciduous, riverine forests in the sub-Himalayan areas of Uttar Pradesh along with *Callicarpa macrophylla* in the third story and with *Cassia fistula, Randia longispina, Zizyphus jujuba*, etc. in the second story. It is found in the first story in savanna forests in the north Indian lower alluvial areas with *Callicarpa arborea* in the second story, as well as in moist deciduous and evergreen mixed forests and on wet savannas in the *Erianthus ravennae* association. He claims that it shows "great sensitivity to frost owing to having large leaves with buds, leaves and internodes possessing hairy, warty or rough surfaces". The species is a strong light demander like teak. Its foliage is gathered and considered good cattle fodder in Madhya, Vidya, and Uttar Pradesh.

Subramanian & Kalyani (1977) declare that *G. arborea* is associated in the so-called southern tropical dry deciduous forests, at an altitude of 600--1100 m., on flat or undulating land and on the lower hillslopes where the annual rainfall is generally between 80 and 100

cm., with *Anogeissus latifolia, Albizzia odoratissima, A. amara, A. lebbek, Amaranthus spinosus, Asystasia dalzelliana, Azima tetracantha, Buchanania lanzan, Butea monosperma, Chloroxylon swietenia, Cochlosperma religiosum, Commiphora caudata, Canthium dicoccum, Cordia dichotoma, Celtis cinnamomea, Cipadessa baccifera, Crassocephalum crepidioides, Coleus forskholii, Croton bonplandianum, Diospyros montana, Donichandrone falcata, Dodonaea viscosa, Elaeodendron roxburghii, Ehretia ovalifolia, Emblica offisinalis, Euphorbia hirta, Grewia abutifolia, G. flavescens, Indigofera cassioides, Leucas hirta, Ligustrum roxburghii, Maytenus ovatus, Olea glandulifera, Pittosporum floribundum, Premna latifolia, Radermachera xylocarpa, Santalum album, Salvadora persica, Soymida febrifuga, Sapindus emarginatus, Scutia circumscissa, Trichodesma indicum, Terminalia chebula, T. crenulata, Tridax procumbens, Vitex altissima, Vernonia divergens,* and *Wendlandia thyrsoidea.*

Benthal (1933) asserts that "The tree is indigenous in most parts of the plains of India and Burma, but is nowhere abundant. It is not wild in Lower Bengal, but is occasionally planted [there] in gardens and villages, and on roadsides.....In Calcutta the new leaves appear in February and March, but in drier climates this takes place later in the year. The flowers appear from February to April, often before the new leaves are open. The tree is bare of leaves for a short time, but the first flowers often appear before the old leaves have fallen. The fruits ripen from April to June. When not in flower the tree closely resembles *Trewia nudiflora* Linn., but the latter may be distinguished by the raised line that joins the bases of each pair of opposite leaf-stalks."

Caaudhuri (1969) encountered *Gmelina arborea* in the so-called "block forests" (which are clear-felled areas of dry mixed forests) in northern Bengal, while Mukerjee (1965) lists it as an invading pioneer tree on the savannas of West Bengal. Palit (1969) reports that it often grows in association with *Shorea robusta* in that same state of India. Deb and his associates (1968) list it from Bhutan.

Cooke (1905) cites unnumbered collections of Dalzell & Gibson, of Ritchie, and of Woodrow from Bombay and declares that the species has been introduced in Sind, Pakistan. He also says that "The root, the bark, and the fruit are used medicinally; the fruit is also eaten by some of the hill-tribes. The timber is excellent, strong and light, does not warp nor shrink, and is valuable for ornamental work."

Brandis (1906) gives its natural distribution as the "Subhimalayan tract from the Chenab eastwards to 3,000 ft. Aravalli hills. Central India. Singbhum. Western Peninsula. Burma." He notes also that the leaves are shed from February to early April and the new foliage appears from late April to May; the flowers appear from February to April, generally before the leaves are fully developed. He also agrees that the species coppices well. Nairne (1894) asserts that it is less common in the Deccan peninsula than it is in Konkan. Babu (1977) tells us that it is a common tree in ravines and on slopes in the monsoon forest of Dehra Dun. Santapau & Raizada (1956) refer to it as "a rare tree in the Gir in the wild state;

we have seen a few plants growing wild, but a fairly large number under cultivation in forest nurseries." They cite four unnumbered collections -- for one of which they note "common in field hedges". Inamdar (1968, 1971), Shah (1969), Jain (1963), Patel (1971) and Santapau (1955) all report it from Gujerat, while Santapau (1967) lists it from Saurashtra. Ellis and his associates (1967) cite their *no. 18678* from Kerala; Vajravelu and his associates (1968) refer to it as common in teak and rosewood plantations in the same Indian state, citing *Vajravelu 19113*.

Subramanyam & Henry (1966) encountered *Gmelina arborea* in mixed deciduous forests at the foot of and on the lower slopes of mountains in Madhya Pradesh, while Rao & Sastry (1964) refer to it as "rare" on exposed hilltops and Joseph (1963) found it "not common" in the same state. Patel (1968) asserts that in Melghat it is "Occasional, but locally frequent at high elevations and in areas cultivated in the past". Deb (1961) cites his *no. 2042* from Manipur. Bhattacharjee & Das (1969) list it from Mysore, where Naithani (1966) refers to it as "rare", citing his *no. 23120*. Razi (1946) also lists it from Mysore, referring to it as a "mesophanerophyte" in the Raunkiaer classification of life forms. Datta (1965) calls it "a moderate-sized tree of the Orissa jungles", while Vyas (1967) refers to it as a "rare tree of slopes and cool valleys" in Rajasthan, citing his *no. 58*.

Sharma and his associates (1978, 1981) cite *Sharma 39816* from Tamil Nadu where the species is said to be only "occasional"; Deb (1968) records it from Tripura, and Gupta (1967) from Uttar Pradesh. Santapau & Shah (1969) found it growing on Salsette island, and Kurz (1870) lists it from the Andaman Islands. Griffith (1854) records it from Upper Burma, from where Merrill (1941) cites *Kingdon Ward 493*.

Clarke (1885) maintains that *Gmelina arborea* occurs "Throughout the Deccan Peninsula and Ceylon, frequent, extending to the foot of the N. W. Himalaya" [Pakistan] and Chittagong [Bangladesh]. Jafri & Ghafoor, in a personal communication to me, describe it as a "rare plant in our area" [Pakistan], but "cultivated as a decorator tree in gardens and avenues". They cite only a single Jan Mohamed collection.

From Sri Lanka the species is listed by Gunawardena (1968); Thwaites & Hooker (1861) cite only *C.P.128 (698)*. Trimen (1895) says of it: "rather common in moist region up to 5000 ft., but often cultivated". Hallier (1918) cites his *nos. 3514* & *C.243*, the latter from cultivated material, but the former from a tree apparently growing wild along the edge of the river adjoining the Sri Lanka Botanical Garden, where, according to observations made by my wife and myself during our visit there, cuttings and trash from the garden are regularly dumped. Hallier also cites *Hosseus 476* and gives the species' overall distribution, as recognized by him, as India, Sikkim, Assam, Bangladesh, Malaya, and the Philippines [the Philippine part of this supposed distribution is erroneous]. Craib (1911) cites *Kerr 540* and *Hosseus 576*, the latter as to flowers only, the leaves being those of *Columbia floribunda* Wall. [=*Colona floribunda*].

Fletcher (1938) cites, also from Thailand, *Annandale s.n.*, *Hosseus*

576, Kerr 540, 2331, 9856, 12356, & *20271* (but the Hosseus collection, again, as to flowers only). He also cites an unnumbered Curtis collection from the Langkawi islands, giving the overall distribution of the species, as accepted by him, as India (type locality), Yünnan, Burma, Indochina, and again erroneously, the Philippine islands. Sawyer & Chermsirivathena (1969) describe it as infrequent in the "phytocenose 1" association, at 310--640 m. altitude, in Thailand.

Dop (1933) cites unnumbered collections by Chevalier, Harmand, Poilane, and Thorel from Annan, Vietnam. He distinguishes *G. arborea* from the closely related *G. racemosa* (Lour.) Merr. as follows: *Gmelina arborea* has the calyx with 5 triangular, apically acute lobes which are 5 mm. long and not glanduliferous, while *G. racemosa* has the calyx truncate and entire, with numerous small vertical glands, the ovary apically pubescent. In *G. arborea* the ovary is externally glabrous.

Corner (1952) reports *G. arborea* as cultivated in Malaya, both as a city tree and by the Forest Service in plantations. Satmoko (1961) lists it as a constituent of the shore vegetation in Java and in the *Barringtonia* formation on the island's sheltered west coast.

Mukherjee & Ghosh (1968) tell us that in India the tree is propagated by seed in the traditional gootee method by the Forest Department. Maheshwari (1918) cites his *no. 1031* from Delhi, where, he says, the species is "Planted in the lawns of gardens. Most of the flowers fall off and [therefore] only a few develop fruit. The tree does not thrive well in the area [of Delhi]." Woodrow (1910) affirms that the seed may be treated like that of teak (*Tectona grandis*), "but large cuttings planted in August and September root freely."

Loudon (1830, 1832) and Sweet (1826, 1830) claim that the species was introduced into cultivation in England from the "E. Indies" [actually, eastern India] in 1812. Misra (1969) reports *G. arborea* grown for timber in India, while Stewart (1972) avers that it is cultivated and naturalized in Sind, "often cultivated on the Pakistan plains and wild from Mirpur and Jammu eastward". Prain (1963) lists it from western and central Bengal, Chota Nagpur, and Chittagong; Das (1964) found it in mixed dry forests in West Bengal. Voigt (1845) lists it as cultivated in Calcutta and its suburbs, while Ghosh (1964) reports it cultivated in plantations by the Forest Service in West Bengal. Collett & Hemsley (1890) report it from the Shan States of Burma, citing an unnumbered Aplin collection.

Dawkins (1919) reports that sambar deer (*Rusa unicolor*) are attracted from "the whole countryside" to *Gmelina* plantations, where they can do serious grazing damage, but "curiously enough, cattle seem to be averse to [it]", refusing even to touch it: "in fact, their presence is looked on as beneficial in keeping down weeds and grass. Even in the dry season, when sambar grazing is at its worst, cattle in these forest regions can find plenty to eat, and seem to dislike yemané [*G. arborea*] as much as they do teak. Ponies also refuse it, so there must be something distasteful in it." Hail storks can do much damage to the young shoots, but "most of the trees will recover without coppicing, and several such storms every

year would be preferable to the visitations of sambar." He recommends short-length timber produced by very heavy thinning over 4 or 5 years, with consequent girth enhancement and shortened rotation. He concludes that "there can be no doubt that this tree....must form an exceedingly profitable crop, providing that localities well suited for export are selected, and floating will always be the cheapest extraction method."

Parker (1924) points out that "The tree would be worth cultivation for timber, but it cannot stand frost in irrigated plantations" [in the Punjab, where it is "not common']. In the mid 1960s Daniel K. Ludwig purchased a 3,000,000-acre tract of virgin rainforest on a tributary of the Amazon river in Brazil on which to grow *Gmelina arborea*. He thought that this tree would produce wood there for pulp and lumber at about ten times the rate of "ordinary" trees. By the end of the "first stage" of this project and the strip-clearing of irreplaceable native vegetation, in 1983, the total cash investment was estimated at about 1 billion dollars. Certainly this is a most grandiose follow-up -- to be deplored from an ecologic viewpoint -- on Parker's modest suggestion in 1924! McIntyre (1972) asserts that those trees that grow straight will have their wood used in cabinet work, the rest for pulp, and that "gmelinas will eventually provide as much as 1,000 tons of pulpwood a day....without exhausting the jungle soils."

Chaudhuri (1925) asserts that in the Chittagong area the tree does not grow with a straight trunk in the wild, but when planted close together in a plantation will grow fast and straight, with an average growth of 51 feet and trunk diameter of 5 inches in 5 years; the largest he observed was 59 feet 5 inches tall, with a diameter at breast height of 7.45 inches. A tree with a 6-foot girth was produced in 30 years. He observes that the tree is often attacked by the beetle, *Calopepla leayana*, which may cause serious damage.

Kowal & Kassam (1978) report that *Gmelina arborea* is an important tree for use in the afforestation of savannas in Nigeria, where it has a very high rate of growth -- "the annual growth increment in Nigeria [being] 16--28 m^3/ha." Bojer (1837) listed it as cultivated in Mauritius (in the botanical garden) already in his time. Molina (1975) found it cultivated in Honduras and Roig (1953) in Cuba. Jiménez (1975) lists it as cultivated in the Dominican Republic and asserts that Dr. Basset Maguire introduced it into the United States as a possible source of paper pulp. Liogier & Martorell (1982) comment that it is "scarcely planted and perhaps escaped in Puerto Rico". Lasser and his associates (1974) report it cultivated in Venezuela, while López-Palacios (1977) says that it is actually cultivated in at least four states of that country, although he cites only his *no. 3096*. In a personal communication he tells me that *Aristeguieta 6933*, in the Caracas herbarium, represents this species and that the tree actually occurs both wild and cultivated in the state of Barinas, Venezuela.

The Baileys (1941, 1976) list the species as hardy in their Lifezone 10, cultivated "along the southern border" of the U.S.A. They list only the Singapore Botanical Garden as a source of the seed in

the horticultural trade. Van Rensselaer (1948) found it in cultivation in California.

Akachuku & Burley (1979) found that individual trees of in plantations varied in fiber length and also in proportion of fiber, vessels, and parenchyma. Yeom & Sandrasegaran (1966) found that the average crown diameter (Kd) and stem diameter (D) are linearly and positively correlated and the correlation may be expressed by this formula: Kd = 1.15 D + 924. They also found a curvilinear relationship between Kd and the total height of the tree, as well as a posit_ e correlation between the total height and the stem diameter. The mean average yield in Malaya, as reported by them, is 3700 cu. ft. per acre for 7--9-year old trees.

Foxworthy (1909) describes the wood as "yellowish, grayish, or reddish white, with a glossy luster, evengrained, soft, light and strong, durable, does not warp or crack. Seasonal rings marked either by a white line or by more numerous pores in the spring wood. Pores large and moderate-sized, often subdivided, rather prominent on a vertical section; sometimes arranged in rough, more or less concentric lines. Pith-rays short, moderately broad, prominent. Wood easily worked and readily takes paint or varnish; it is very durable under water."

Hughes & Esan (1969) have investigated the variation in the structural features and properties of the wood as a result of changes in population density. They found density to be strongly correlated (in simple correlation) with fiber length, distance from the pith, and age.

Fox (1967) describes the establishment practices, growth figures, and thinning techniques used in *Gmelina* culture in Sierra Leone. Growth data and preliminary volume tables based on simple plot measurements are discussed and the silvicultural conflict between espacement, loss of increment, and the phenomenon of dieback are described.

Ojenyi & Agbede (1980) have reported on the effect on soil fertility of inter-planting a forest crop of *Gmelina* with food crops in Southern Nigeria. Inter-cropping with yam, maize, and cassava caused no significant change in soil fertility, but a slight reduction in soil organic carbon and increase in soil N and P were observed. No definite change in pH was observed. "The investigation therefore further supports the practise of agri-silviculture [simultaneous production of forest and food crops on the same area of land] as a means of increasing food production in the tropics." When all the food crops were combined on a *Gmelina* plot, the girth and even survival of *Gmelina* after two years were usually relatively low, but the difference in the agronomic performance of *Gmelina* due to intercropping with individual but different food crops were not significant. The yield of food crops grown on *Gmelina* plantations compared favorably with that from unfertilized arable plots planted to the food crops alone.

[to be continued]